

## **Modelling the Electromagnetic field coupling into a Car using a Finite Boundary Element code.**

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### **ABSTRACT**

This paper presents numerical results which have been generated at EADS CRC, using an electromagnetic boundary element software (ASERIS), as part of the GEMCAR project. GEMCAR is a European Project dealing with the numerical modelling of Automotive Electromagnetic Compatibility (EMC) situations.

Preliminary simulation results are presented which show that there is good agreement between Finite Boundary Element method for antenna and car models, and measured data obtained from the MIRA Semi-Anechoic chamber.

Comparisons between different simulation techniques among the GEMCAR partners are also presented.

### **I INTRODUCTION**

Electromagnetic modelling of vehicles has been an active area for research over a period of many Years. During this time there have been a number of methodological advances in Computational Electromagnetics (CEM) and there have also been substantial increases in the calculation speed and data-handling capacity of computers. The improvements in computational power, and the falling cost of high-performance computers, has allowed CEM to model large and complex structures such as cars and aeroplanes .

CEM is used extensively to evaluate new designs, to validate measurements and in some cases to justify design changes. GEMCAR (Guidelines for Electromagnetic Compatibility modelling for Automotive Requirements) is a three year European project which aims to produce a freely available guidelines document for the numerical modelling of Automotive Electromagnetic Compatibility (EMC) situations.

The consortium that is carrying out the project includes partners from the aeronautical and automotive industry with experience in electromagnetic modelling. One of the major aims of the project is to highlight the potential uses of modelling in the design and test phases of the vehicle development life cycle, and also the type of CAD data which is required, the technical skills which are required to carry out the work, and level of computing resources which are required.

This paper will focus on the numerical technique developed at EADS CRC based on a Finite Boundary Element code linked with a cable network code. Preliminary results of simulations for an antenna and real vehicle in a semi-anechoic chamber are presented and compared with measurements and with other EMC techniques used in the Project.

### **II MODELS**

The GEMCAR validation models have been chosen to represent various complexity levels and physical situations. In this paper two of the simplest of these test cases will be described. In the first of these, the electric field generated by an antenna is validated against measurements. In the second, a vehicle bodyshell is illuminated by this antenna. The numerical techniques used at EADS CRC to describe the antenna and the car models are based on the software ASERIS-BE for the 3D calculations on the antenna and the car, and ASERIS-NET for the coupling with the cables inside the vehicle.

#### **1) Antenna model**

The antenna used for the measurements is Biconical hybrid. This type is widely available, and is commonly used for immunity-type EMC measurements. It was chosen as it has a broad frequency range covering 20 MHz to 1 GHz, which is the main band of interest in the European Automotive EMC directive 95/54/EC. The antenna was introduced into a Semi-Anechoic Chamber (SAC) at MIRA and used to illuminate a volume of space. The electric field strength was measured at various points in front of the antenna in vertical polarisation. These points were chosen to represent the envelope of the vehicle which was installed in the tests. A reference point was chosen in the chamber and the relative field at each of the other points was recorded for use in the comparison of measurements and different model results (this approach is described in [0]). A model was constructed of the experimental set-up and a prediction for the relative field strength was calculated.

#### **2) Vehicle model**

The CAD data for the vehicle, provided by VOLVO Car Corporation, was simplified before any attempt was made to apply meshing techniques for numerical modelling. This was carried out in order to remove some of the complexity of the real car, and to reduce the amount of meshing problems. The full CAD data of the vehicle is many hundreds of megabytes, and some of the information contained in it is not required for electromagnetic modelling. In addition some components were deliberately removed to reduce the complexity of the initial model validation trials.

A ground plane was modelled underneath the vehicle which was positioned so as to represent the full vehicle standing on its wheels on a conducting floor, in the MIRA semi-anechoic chamber (see Fig. 1).



Fig 1: MIRA Semi Anechoic chamber: the antenna and the car

### 3) The 3D Boundary Element Code ASERIS/BE.

This software solves the Maxwell equations in the frequency domain by a finite boundary element method. This code is widely used for EMC and antenna applications for complex geometry.

Interfaces with CADD5, CATIA, I DEAS SDRC modeling software are used to build the mesh.

The quality of the expected results depends on the quality of meshing used. The size of the meshing elements should not be too large with respect to wavelength: one generally uses a rule of one-fifth of the wavelength  $\lambda$  (on average, the size of each edge of the meshing triangle will be  $h = \lambda/5$ ).

This solver does not handle directly SDRC Universal formatted files. A pre-processor analyses the electromagnetic complexity of the structure, and enables assigning to the meshing edges the degrees of freedom unknowns required to solve the Maxwell Equations.

For surface elements, these unknowns are the electric and magnetic current fluxes of induced currents across the mesh edges. They are located at the middle of the sides of triangles. For one given frequency, the code assembles one matrix, factorizes it, then solves a linear system, with the right hand side containing the illumination distribution.

A frequency value or a frequency range and a step are set for the calculation.

The main limitation of these techniques is in the memory requirement, because a dense matrix containing the interactions between the different cells has to be stored.

Electromagnetic fields are calculated in the vicinity of the structures at particular points defined by the user. Calculation of the diffracted field, by subtracting the incident field from the total field is :

$$\begin{aligned} E_{dif}(x) &= E_{tot}(x) - E_{inc}(x) \\ H_{dif}(x) &= H_{tot}(x) - H_{inc}(x) \end{aligned}$$

The field diffracted at any point  $x$  of a homogeneous domain is expressed by a surface integral on the boundary of that domain. For a perfect conductive object, this expression depends on the surface electric surface currents through an integral-differential operator.

### 4) The cable network code ASERIS/NET.

The 3D Finite Boundary Element code can be used to compute the incident field on a wiring, the response of the wiring being solved with a cable network code. The method theoretically comes from the "field-to-transmission-line" model. In this model, the incident field is transformed into equivalent generators, driving currents on the wiring. In this approach, it is important to understand that "incident" field means the field in the absence of the wiring. Therefore, the 3D incident field calculation does not require the wires to be meshed, which may be seen as a great advantage.

Taylor's model is (see Fig. 2) the most suited for a multiconductor transmission line model. It stands that the coupling of an incident field on a wiring is equivalent to applying a set of distributed current and voltage generators,  $I_s$  and  $V_s$  respectively. For a simple transmission line, the two generators are defined in the following way :

$$\begin{cases} V_s = -j\omega\mu_0 \cdot \int_0^h H_y^{inc} \cdot dz \\ I_s = -j\omega C \cdot \int_0^h E_x^{inc} \cdot dz \end{cases}$$

"C" being the capacitance of the line.

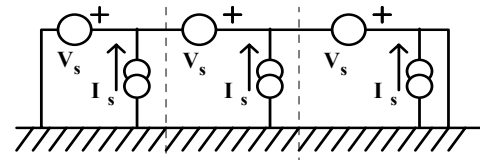


Fig.2 : Taylor representation

ASERIS-NET simulates the interference on an electrical or electronic network, resulting from local injections and distribution sources, due to natural or artificial external ambiances or electromagnetic disturbances. These field injections are computed by the 3D code and are coupled on the cables by solving the transmission line equations in the frequency range of interest.

Input parameters for the simulations described below are the bundle (single conductor wire) electrical characterisation (RLCG matrices), the various geometrical shapes of the bundles, shield or non-shield and integration of dielectrics in the wires, the loads or devices: linear circuits (R, L, C...). Outputs used for our simulations are frequency domain currents and voltages at any point of the network. Scattering parameters between network ports can also be computed from these currents and voltages.

## III NUMERICAL RESULTS

Antenna biconilog calibration and Volvo car illumination by the biconilog antenna have been investigated in the MIRA Semi Anechoic chamber environment.

To test these interactions, different numerical techniques have been used in the GEMCAR Project, to carry out a cross validation exercise. These techniques are :

- Boundary Element (ASERIS BE) method (EADS)
- Transmission-Line Modelling (TLM) method (MIRA)

- The Finite Difference Time Domain (ONERA DF ALICE) and the Hybrid Finite Volume method (ONERA HYB) and coupling with CRIPTE code (ONERA CERT).

- Method of Moments (EPFL)

Measurements have also been carried out at MIRA, to compare with the models (referred to as MIRA SAC).

### 1) Calibration of the biconilog Antenna

The EMCO biconilog antenna (type: 3143, bandwidth: 20-1000 MHz) is aligned with the vehicle. For the antenna calibration without the test object present, field data can be collected at the points required for front polarisation.

The antenna is meshed using I DEAS SDRC software.

Figure 3 below illustrates the comparison between measurements and other simulation techniques, for two points in the chamber (electric field divided by the value at the reference point).

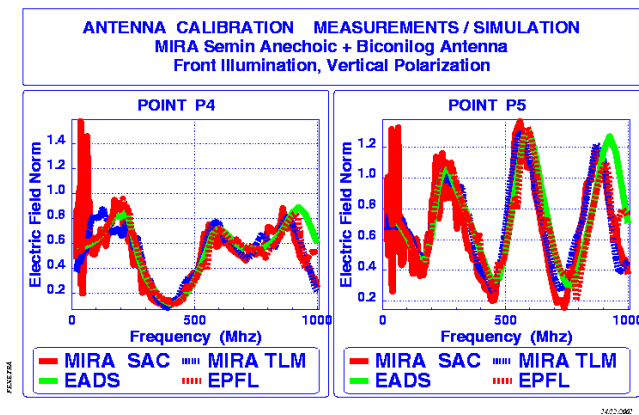


Fig.3 : Normalized Electric Field amplitude for two points of calibration : comparisons of various methods.

Overall it was found that the agreement was reasonably good. The models seem to agree with each other fairly well, except at low frequencies (< 100 MHz) where the effects of the chamber walls dominate the measured results).

### 2) Simple Test car illuminated by the SAC biconilog Antenna

The simple test case is a vehicle body (without doors, bonnet and boot). The antenna is aligned front with the vehicle (see Fig. 4). The antenna and the car are meshed by I DEAS SDRC software and the illumination effect on the car is computed at EADS CRC, using the Boundary Element Code.

Some indications about the mesh (car + antenna) :

- Number of of freedom unknowns = 20503
- Number of vertices = 8573
- Number of elements (triangles) = 14548
- Typical size of edge = 7 cm
- Time of computation = 1/2 hour by frequency on a 16 processor parallel computer

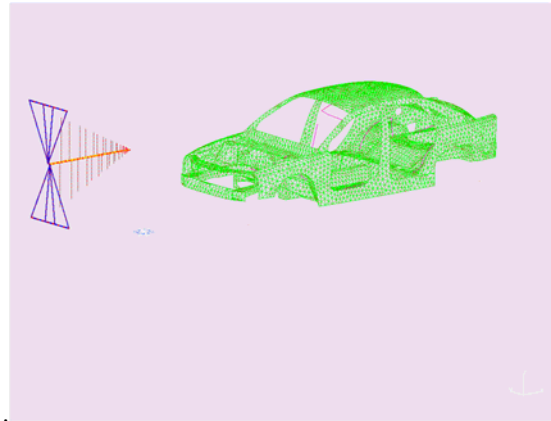


Fig.4 : Antenna , Car simple test case mesh and harness path

Below, figure 5, some comparison results with measurements and other techniques at two points inside the vehicle are plotted.

The models used all gave similar results, despite major differences in their formulation.

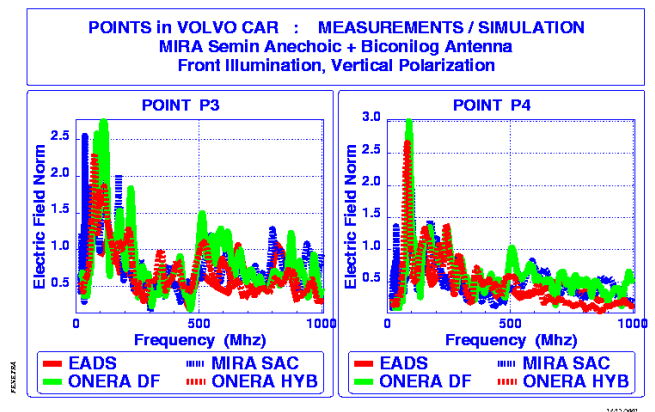


Fig.5: Normalized Electric Field amplitude for two points of observation in the car : comparisons for various methods.

### 3) Simple Test car illuminated by the SAC biconilog Antenna + simple harness = S parameters computation.

Finally, a « virtual single conductor harness » is positioned at 2 cm from the vehicle bodyshell, following the path plotted figure 4. The harness is not meshed and the electric and magnetic field coupling between the 3D code and the network code is used. The scattering parameters obtained from the simulations are shown in the following figure (Figure 6) and compared with ONERA (electric tangential Agrawal coupling method) simulation method and MIRA measurements. The agreement is again reasonable .

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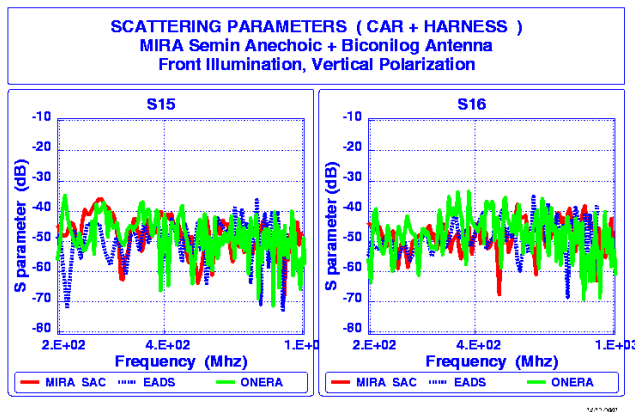


Fig.6 : Comparison of scattering parameters for two ports of the harness in the car.

## IV CONCLUSION

The results demonstrate that good agreement can be achieved between the Boundary Element method results from EADS CRC and other numerical results generated by the GEMCAR partners, in the modelling of a relatively sophisticated antenna model and simplified but realistic car model. Comparison with measurements for antenna calibration, 3D car computations and coupling with simple harness inside the car have been investigated. The results have given confidence to continue with the model validation activity with more realistic models of the vehicle.

## V ACKNOWLEDGEMENT

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